INFLUENCE OF SHOOT NUMBER ON THE GLOBAL PRODUCTIVITY OF POSITIONED AND NON-POSITIONED TRAINING SYSTEMS

INFLUENCE DE SHOOT NUMÉRO SUR LA PRODUCTIVITÉ GLOBALE SUR LES SYSTEMES POSITIONNÉS ET NON-POSITIONNÉS

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Abstract

The global productivity of a vineyard is conditioned by the development of leaf area. The shoot density and the spatial distribution of leaf area influence the porosity of the canopy and the production of dry matter. The aim of this study was to determine the influence of the shoot density in the production of biomass in renewable parts and in the canopy microclimate, in both positioned and non-positioned training systems. The trial was developed during 2013 and 2014, in a Cabernet Sauvignon vineyard in Albacete (Spain). In two different training systems, one positioned -Vertical Shoot Positioned (VSP)- and another not positioned -Sprawl-, three levels of shoot density were established: 35 000, 55 000 and 70 000 shoots per hectare. At maturity the total leaf area, the external leaf area and the volume occupied by the canopy were determined, and the leaf area density was calculated. At the end of ripening, the biomass produced in renewable vegetative organs –leaves and shoots- and reproductive organs -cluster - were determined. The higher the shoot density was the greater the production of total biomass, due to increased biomass production in clusters. The individual shoot vigour offset the differences in shoot density, so no differences were observed in the production of vegetative biomass due to the shoot density. The increases of vegetative growth and biomass accumulation due to increased shoot density were higher in Sprawl, the not positioned training system, than in VSP, the positioned one. In 2013, with the increasing of the density of shoot, the amount of biomass produced by leaf area increased in both training systems. But in 2014, no significant differences were found. The increase of leaf area density caused by the increase of the shoot number was higher in VSP than Sprawl. With higher density of shoot, canopy have higher densities of leaf area and therefore less porous.

Keywords : *shoot density, training system, leaf area density, biomass accumulation.*

Résumé

Le potentiel de production global d'un vignoble est conditionnée par la mise au point de la surface des feuilles. La densité de rameaux et la distribution spatiale de la surface foliaire influencent la porosité du feuillage et de la production de biomasse. Le but de cette étude était de déterminer l'influence de la densité des rameaux dans la production de biomasse dans les parties renouvelables et le microclimat du système, les deux systèmes de conduite positionnés et non positionnés. Le procès est déroulé durant les années 2013 et 2014, dans un vignoble Cabernet Sauvignon (Vitis vinifera L.) à Albacete (Espagne). En deux systèmes de conduite, un positionné - vertical shoot positioned (VSP) - et un none-positionné -Sprawl- trois niveaux de densité de rameaux ont été établis: 35 000, 55 000 et 70 000 rameaux par hectare. A maturité la surface foliaire totale, la surface foliaire exposée et le volume occupé par la canopée ont été déterminées, et la densité de surface foliaire a été calculée. À la fin de la maturation déterminé la biomasse produite dans les organes renouvelables, la différenciation entre les organes végétatifs –feuille et branches- et reproducteurs -grappe-. L'augmentation du nombre de rameaux causé une augmentation de la biomasse totale en raison de la production accrue de la biomasse dans les grappes. La croissance de l´unité de rameaux compensé les différences de densité de rameaux, de sorte qu'il n'y avait pas de différence dans la biomasse accumulée dans les organes végétatifs. Les augmentations de la croissance végétative et l'accumulation de la biomasse en raison de la densité des rameaux accrue étaient plus élevés dans Sprawl, le système de conduite non positionné, que dans VSP, l'un positionné. En 2013, avec l'augmentation de la densité de rameaux, la quantité de biomasse produite par la surface foliaire a augmenté dans les deux systèmes de conduite. Mais en 2014, aucune différence significative n'a été trouvée. L'augmentation de la densité de surface foliaire causée par de augmentation du nombre de rameaux était plus élevée dans VSP que Sprawl. Avec une densité plus élevée de rameaux, moins poreuse feuillage avec des densités plus élevées de la surface foliaire.

Mots-clés : densité rameaux, système de conduite, haie foliaire densité, accumulation de biomasse.

1. Introduction

The leaf area of the vineyard is a key factor in overall productivity and in the characterization of light and thermal microclimate of the grape vine. Foliar surface area is the most used variable for the description of the vegetative development of the plant, defined as the ratio of the surface area of the leaves and soil (Champagnol, 1984). Furthermore, training systems determine the spatial distribution of the aerial organs of the strain, influencing the photosynthetic efficiency and therefore in overall productivity. The porosity of the training system will be determined by the number of aerial organs and the form of plant´s distribution. No positioned systems are free or semi-free systems that place the vegetation allowing a high porosity of the canopy, while positioned systems lead the vegetation conditioning canopy layout and its microclimate (Smart and Robinson, 1991).

2. Material and Methods

The study was carried out during 2013 and 2014 in a commercial Cabernet Sauvignon vineyard located in the locality of La Roda (Albacete, Spain, 39º 05 '28' 'N, 2 ° 19' 54''W, 810 m amsl). In 2013 and 2014, they were recorded 1823 and 2024 GDD (growing degree days, base 10 ° C) and precipitations of 208 and 111 mm, respectively. In two vineyards with different training systems –vertical shoot positioned and sprawl, abbreviated as VSP and S-, three levels of shoot´s density -35000, 55000 and 70000 shoots/ha, abbreviated as 1, 2 and 3- were evaluate.

In the vineyard with the training system VSP, the Cabernet Sauvignon plants (clone 169), grafted onto 420A, were planted with a vine spacing of 2 x 1 m. In the vineyard with the training system Sprawl, the Cabernet Sauvignon plants (clone 1D), grafted onto 161-49C, were planted with a vine spacing of 3 x 1.2 m, (Table 1). In each vineyard or training system, were established four replications for each shoot´s density, resulting in two trials with a randomized block design.

Table 1. *General characteristics of grapevine training systems and shoot density used in the trial.*

Tableau 1. Caractéristiques générales des systèmes de formation de la vigne et de la densité de rameaux utilisés dans le procès.

						Nº Shoots		
Cultivar	Clone/Rootstock	Training system	Vine spacing	Nº Plants/ha	Units	Tto 1	Tto 2	Tto 3
Cabernet Sauvignon	169/420A	VSP Cordon Royat	2x1	5 000	nº/m.l	7	11	14
					nº/vine	7	11	14
					nº/ha	35 000	55 000	70 000
Cabernet Sauvignon	1D/161-49C	Sprawl	3x1,2	2 800	nº/m.l	10	16	21
					nº/vine	12	19	24
					nº/ha	33 333	52 778	70 000

During the maturation, the leaf area index (LAI) and the volume occupied by the vegetation (V) were measured. Leaf area density (LAD) was calculated by dividing the total leaf surface between the volume occupied by the vegetation. During the harvest were determined the throughput and their components (number of shoots per grape vine, clusters / shoot, cluster weight, number of grapes per cluster and grape weight). In winter the weight wood pruning and weight of vine shoots were determined.

The global productivity is determined by the accumulative dry matter (dry weight) in renewable plant organs-leaves, stems and clusters-. The measures of performance of the crop and the wood pruning weight were considered as fresh weights of clusters and shoots. The leaves were collected at harvest. Samples of clusters, leaves and shoots were collected to determine the relationship between fresh weight and dry weight (oven-dried at 85 °C to constant weight).

For statistical analysis of the results was use the SPSS v.19.0 software (SPSS Inc. Headquarters, Chicago, Illinois). The results were performed by analysis of variance for probability levels of $p \leq 0.05$ (*); $p \leq 0.01$ (**); $p \leq 0.001$ (***), evaluating the differences between the treatments with the Duncan's test for multiple probability level of $p \leq 0.05$.

3. Results and discussion

By increasing of the shoot density increased total accumulative dry matter, vegetative and reproductive, as observed by other authors (Miller and Howell, 1998), although clusters biomass have increased significantly more than vegetative. Increased biomass production by increasing the load was similar to VSP and Sprawl (Table 2). Both VSP and Sprawl, increased biomass accumulated in clusters with increasing load was the main cause of the increase in overall biomass.

Table 2. *Values of total dry matter produced per area (MStotal, kg/m²); % vegetative dry matter (% MSveg); % reproductive dry matter (% MSrepr). For the three treatments in VSP and Sprawl systems in 2013 and 2014. Level of significance: ***, **, * y ns: significant: Significant a p≤0,001; p≤0,01; p≤0,05 and ns: not significant, respectively. Figures with the same letter are statistically equal by Duncan test for p≤0,05.*

Tableau 2. Valeurs de la matière sèche totale produite par unité de surface (MStotal, kg/m²); % de matière sèche végétative (% MSveg); % de matière sèche reproduction (% MSrepro). Pour les trois traitements dans VSP et Sprawls systèmes en 2013 et 2014. Niveau de signification: ***, **, * et ns: significative: a p≤0,001 significative; p≤0,01; p≤0,05 et ns: non significatif, respectivement. Figures par la même lettre sont statistiquement égal pour p≤0,05 par test de Duncan.

	MS total (kg/m²)		**% MS veg**		**% MS repr**	
Tto	2013					
Cs S1	0.51	c	0.60	a	0.40	b
Cs S2	0.69	b	0.55	ab	0.45	ab
Cs S3	0.85	a	0.46	b	0.54	a
Sig.	**		*		*	
Cs E1	0.54	b	0.58	a	0.42	b
Cs E2	0.85	a	0.49	b	0.51	a
Cs E3	0.84	a	0.45	b	0.55	a
Sig.	***		**		**	
	2014					
Cs S1	0.53	c	54.80	a	45.20	b
Cs S2	0.71	b	49.65	ab	50.35	ab
Cs S3	0.81	a	48.08	b	51.92	a
Sig.	***		*		*	
Cs E1	0.63		57.50		42.50	
Cs E2	0.68		55.13		44.87	
Cs E3	0.77		56.19		43.81	
Sig.	ns		ns		ns	

In both training systems the vigour was reduced with the increasing load (Table 3). However, the number of shoot offset the reduction in vigour, and finally no difference in the weight of pruning wood. Considering as appropriate vigour recommended by Smart and Robinson (1991), 20-40 g/shoot, the vigor was elevated in all shoot density in VSP, and in the shoot densities lower and middle in Sprawl. While in Sprawl an overall reduction in vigor was observed in 2014 respect to 2013, VSP an increase was observed, although this was due to irrigation management.

Leaf surface density increased with increasing density of shoots on both drive systems (Table 4), although the effect was only statistically significant in 2014. The increased of shoot density supposed a greater increase of the total leaf area than the volume occupied by it, reducing porosity systems. Stacking vegetation was much lower in Sprawl than VSP. In Sprawl, leaf area density was lower than 3 m^2 / m^3, while in VSP was greater than 7 m^2 / m^3. Gladstone and Dokoozlian (2003) considered that low values were those under 3 and 5 m^2 / m^3, for systems non-positioned and positioned, respectively; and high values those aged 7 and 6 m^2 / m^3, non-positioned and positioned respectively systems. Considering the vine spacing of each training system, LAD values in Sprawl system are obtained at least 6 times less than VSP system.

The increased load caused the increased of the Ravaz Index in both training systems (table 3). The values of low shoot densities, were than the recommendation of 4-10 made by Kliewer and Dokoozlian (2005) for warm areas, indicating an unbalance because excessive vegetative growth.

Table 3*. Values of pruning wood weight per area (PWW, kg/m^2); weight vine shoot (W.shoot, g); Ravaz index (kg grapes/kg shoot). For the three treatments in VSP and Sprawl systems in 2013 and 2014. Level of significance: ***, **, * y ns: significant: Significant a p≤0,001; p≤0,01; p≤0,05 and ns: not significant, respectively. Figures with the same letter are statistically equal by Duncan test for p≤0,05.*

Tablau 3. Valeurs de poids de bois de taille par zone (PWW, kg/m^2); poids rameaux (W.shoot, g); Indice Ravaz (kg de raisins/kg rameaux). Pour les trois traitements dans VSP et Sprawl systèmes en 2013 et 2014. Niveau de signification: ***, **, * et ns: significative: a p≤0,001 significative; p≤0,01; p≤0,05 et ns: non significatif, respectivement. Figures par la même lettre sont statistiquement égal pour p≤0,05 par test de Duncan.

Tto	PWW (kg/m^2)		W. shoot (g)		Ravaz Index (Kg grape/Kg shoot)	
			2013			
Cs S1	0.31		89.19	a	2.99	c
Cs S2	0.29		55.16	b	5.31	b
Cs S3	0.28		43.15	c	6.53	a
Sig.	ns		***		***	
Cs E1	0.27		75.21	a	2.61	c
Cs E2	0.29		52.56	b	4.48	b
Cs E3	0.31		44.07	b	5.45	a
Sig.	ns		***		***	
			2014			
Cs S1	0.25		73.08	a	3.48	b
Cs S2	0.29		54.01	b	5.13	a
Cs S3	0.27		40.90	b	5.79	a
Sig.	ns		***		**	
Cs E1	0.31	b	84.16	a	1.74	b
Cs E2	0.31	b	58.14	b	3.12	a
Cs E3	0.35	a	51.61	c	3.26	a
Sig.	*		***		**	

Table 4*. Values of leaf area index (LAItotal, m^2•m^{-2}); leaf area index of shoot (LAIshoot, m^2); leaf area density considering vine spacing (LAI/Vol/m^2, m^2/m^3);leaf area density (LAI/Vol, m^2/m^3). For the three treatments in VSP and Sprawl systems in 2013 and 2014. Level of significance: ***, **, * y ns: significant: Significant a p≤0,001; p≤0,01; p≤0,05 and ns: not significant, respectively. Figures with the same letter are statistically equal by Duncan test for p≤0,05.*

Tablau 4. Valeurs de l`indice de surface foliaire (LAItotal, m$^2$•m$^{-2}$); l`índice de surface foliaire rameaux (LAIshoot, m2); densité de surface foliaire considérant espacement vigne (LAI/Vol/m2, m2/m3); densité de surface foliaire (LAI/Vol, m2/m3). Pour les trois traitements dans VSP et Sprawls systèmes en 2013 et 2014. Niveau de signification: ***, **, * et ns: significative: a p≤0,001 significative; p≤0,01; p≤0,05 et ns: non significatif, respectivement. Figures par la même lettre sont statistiquement égal pour p≤0,05 par test de Duncan.

Tto	LAI shoot (m^2)		LAI total (m^2·m^{-2})		LAI/Vol/m^2 (m^2/m^3)		LAI/Vol (m^2/m^3)	
			2013					
Cs S1	0.84	a	2.79	b	0.80		2.88	
Cs S2	0.60	b	3.17	ab	0.86		3.10	
Cs S3	0.52	b	3.47	a	0.97		3.48	
Sig.	***		*		ns		ns	
Cs E1	0.72	a	2.51	ab	5.27		10.50	
Cs E2	0.44	b	2.41	b	5.25		10.50	
Cs E3	0.42	b	2.94	a	6.29		12.60	
Sig.	***		*		ns		ns	
			2014					
Cs S1	0.64	a	2.12	b	0.60	b	2.21	b
Cs S2	0.50	b	2.63	a	0.77	a	2.67	a
Cs S3	0.40	c	2.69	a	0.78	a	2.73	a
Sig.	***		***		**		*	
Cs E1	0.73	a	2.52	b	3.98	c	7.90	c
Cs E2	0.48	b	2.63	b	4.60	b	9.20	b
Cs E3	0.43	b	3.03	a	5.48	a	10.90	a
Sig.	***		*		***		***	

4. Conclusion

The increased of shoots density in non-limiting conditions for an increase of plant biomass production, increasing in greater proportion the reproductive part than the vegetative, decreasing the vegetative growth of shoot and therefore the growth of the total leaf area was contained. In non-positioned systems, the increased load has influenced in smaller proportion in the porosity of the system than the positioned systems. As a free system, the increased leaf area occupies higher volume and lesser extent condition the microclimate of the plant and therefore the global productivity efficiency.

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